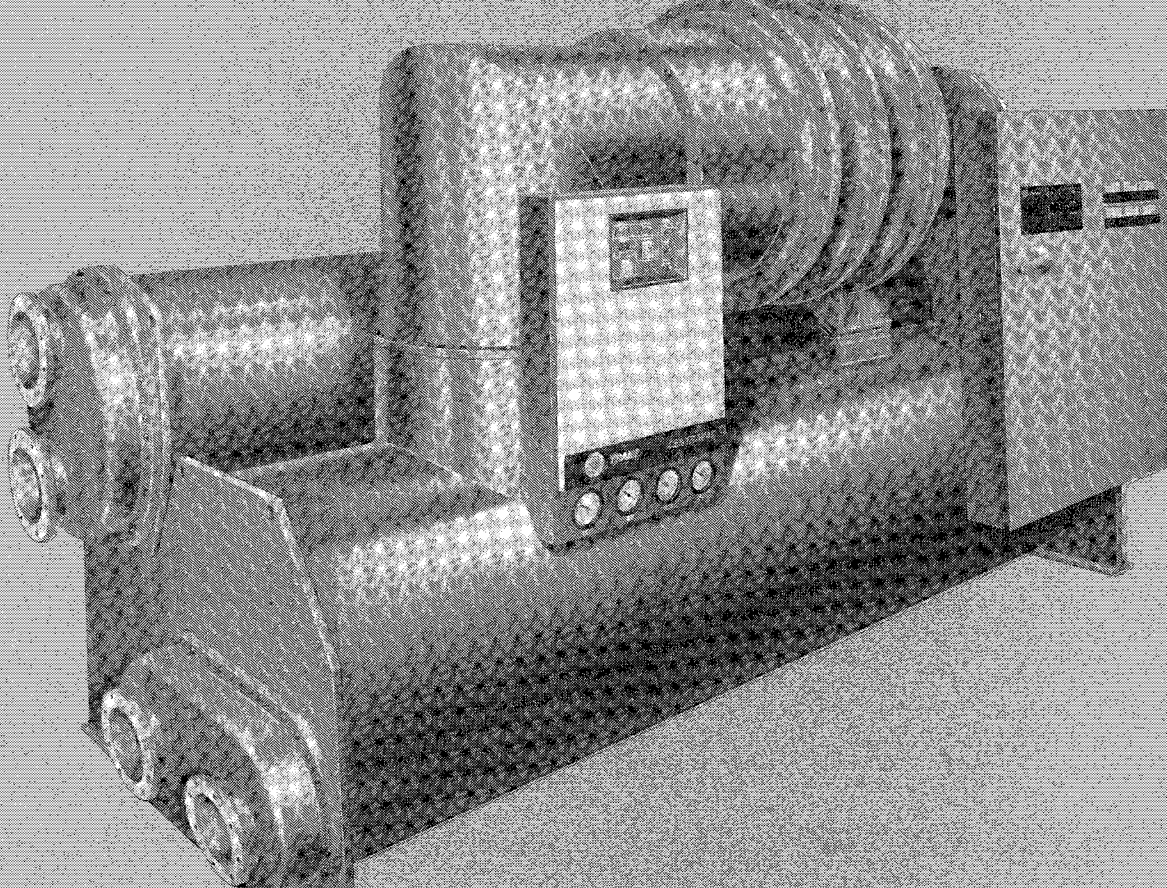
TRANE™

Applications Engineering Manual

Model CVHE CenTraVacs With Microprocessor Based Control



Model CVHE CenTraVacs With Microprocessor Based Control

The Trane Company, La Crosse, Wisconsin 54601

Purpose

This manual has three purposes:

- To provide a hardware description of the standard single-unit control system and components,
- To provide an explanation of the control system's operation and function,
- To provide information regarding the application of the standard control system to various CenTraVac configurations.

Note: The descriptions in this manual apply specifically to design sequence K CenTraVacs (the tenth digit in the CenTraVac model number is "K"). Other models may vary in detail.

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Hardware

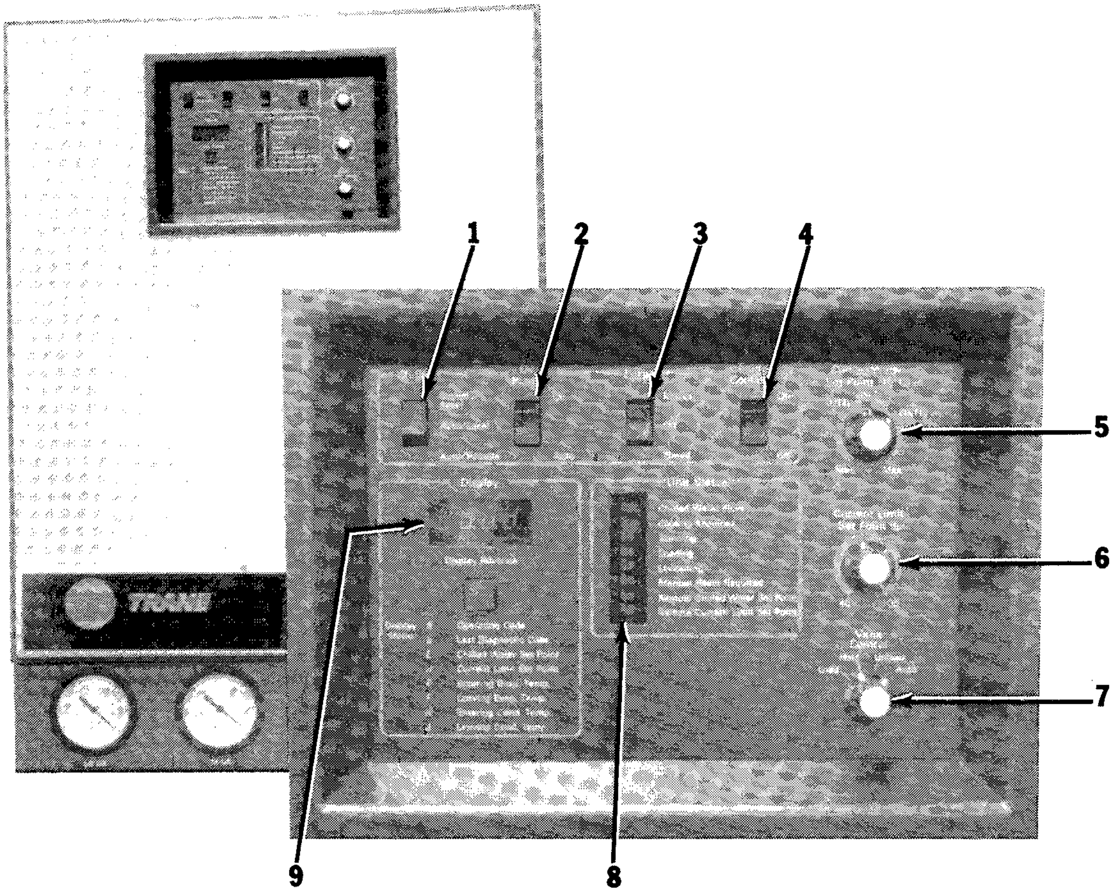


Figure 1

Figure 1 shows the CenTraVac, microprocessor-based, unit control panel (UCP 695), highlighting the man-machine communication adjustments and displays. The communication capabilities are divided into "inputs" and "outputs".

(Note: It may be helpful to refer to the complete electrical line diagram, Figure 5, page 10, when specific component references are made.)

Inputs

1. Chiller Switch. . . This 3-position switch determines CenTraVac operating mode:

Standby/Reset. With power applied and the switch in this position, the control system is armed, but unit operation is prevented. The operating code "A 0" appears on the display. This position is used by the operator to clear a latching diagnostic (a fault requiring manual reset).

Auto/Local. In this position, the CenTraVac is allowed to run automatically in response to the panel control settings.

Auto/Remote. In this position, the CenTraVac runs automatically in response to setpoints established at a remote device and communicated to the panel via the optional "Serial Communications Interface" (SCI). If no SCI link exists, or there are no remote setpoints established, control reverts to the local settings.

2. Oil Pump Switch. . . This 2-position switch determines the operating mode for the lubricating oil pump motor.

On. In this position, the oil pump motor runs continuously. The CenTraVac cannot start when this switch is on. This switch position should only be used by a competent service engineer since a latching diagnostic will occur, requiring manual reset.

Auto. This is the normal position. Operation of the lubrication system is supervised by the Unit Control Module (UCM).

3. Purge Switch. . . Any of three operating modes can be selected:

Manual. The purge unit will run continuously in this position. Refer to "Operation-Maintenance CVHE-M-3" to properly operate the purge system in this mode.

Off. When this switch is in this position, the purge system will not operate UNLESS it is already running in the "timed" mode. WARNING: The purge unit can operate, under certain conditions, with the switch in the "off" position.

Timed. This is the normal position. The purge unit operates in response to a timer and a purge pressure switch. The purge compressor will be run five minutes out of every two hour period of chilled water system demand. Operation is extended automatically by four minutes whenever the pressure switch indicates noncondensibles remain in the CenTraVac. The run time is again extended so long as the pressure switch remains unsatistfied.

4. Free-Cooling (Optional)...Operation of the "Free-Cooling Option" requires this switch to be turned "on" manually. A set of free-cooling valves are opened and the compressor is prevented from running. When this switch is turned "off", the compressor will not be allowed to restart until the free-cooling valves have repositioned closed.

When the CenTraVac is equipped with the (remote) SCI option, free-cooling can be turned on or off remotely, regardless of the position of this (local) free-cooling switch.

5. Chilled Water Setpoint....This manually adjustable potentiometer is used to establish the setpoint for the leaving chilled water (supply) temperature. Remember, this is the SETPOINT (an input value), and not the actual supply chilled water temperature.

6. Current Limit Setpoint....This manually adjustable potentiometer is used to establish the load limiting (current) setpoint. Continuously variable dial settings between 40 and 100 percent of motor "rated load amps" (RLA) are available. This, also, is an input value and does not reflect the actual motor current.

7. Vane Control Switch....This 4-position switch determines what signals are sent to the compressor inlet vane operator.

Load. As long as the vane control switch remains in this position, the "vanes open" relay (1U1Q7) is continuously energized. Normal automatic vane control is suspended. However, three limiting actions take precedence over manual loading...1) motor current limit, 2) condenser pressure limit, and 3) evaporator temperature limit. Approach to any of these three limits supercedes manual loading.

Hold. With the vane switch in this position, both the "vanes open" relay (1U1Q7) and the "vanes close" relay (1U1Q8) are de-energized. Inlet vanes will remain in their present position, unless one of the three limits (motor current, condenser pressure, or evaporator temperature) is approached. The "hold" position also redefines the menu of codes appearing in the "condition display window". A further explanation of this is found under "Display", page 4.

Unload. This switch position energizes the "vanes close" relay (1U1Q8). Automatic inlet vane control is suspended.

Auto. This is the switch's normal position. Inlet vanes are controlled automatically by the controller microprocessor, or "unit control module" (UCM). Details of this controller's action are found under "Capacity Control", page 14.

Outputs...Status Lights (Figure 1)
A series of eight status indicator lights (8) are located directly below the purge switch. These blue lights provide the operator with specific CenTraVac system information. The first four lights are sequential. That is, they will only light in sequence. The remaining four can light out of sequence.

- Chilled Water Flow...Illumination of this light occurs when the chilled water flow switch (5S2) is closed, indicating water flow in this circuit.

- Cooling Required...This light illuminates only when chilled water flow is established and the controller (UCM) detects a demand for cooling. A requirement for cooling is found when the leaving chilled water temperature exceeds the chilled water setpoint by a value greater than the "differential-to-start" criteria (a variable input to the UCM, as described on page 9).

- Running...This light will illuminate when the chiller is running in either of the two "Auto" (chiller switch) modes, and the starting sequence is complete. It will also remain lit when the unit is in its post-lube cycle, even though the compressor has been shut down.

- Loading...This light glows when the inlet vane operator is opening the vanes. It is normal for signals to the inlet vane operator to occur in short pulses.

- Unloading...Likewise, this light glows when the inlet vanes are being moved toward the closed position.

- Manual Reset Required...This light indicates that a latching diagnostic has occurred and the chiller is shut down. Unit operation cannot resume until the chiller switch is manually placed in "Standby/Reset" and returned to one of the "Auto" positions.

- Remote Chilled Water Setpoint...This light indicates that a remote device (through the SCI) has established the setpoint. The local setpoint is ignored unless the SCI link is broken. It will also light when either of the chilled water reset options is active.

- Remote Current Limit Setpoint. . . Similar to the action of "Remote Chilled Water Setpoint", above, this light indicates that a remote device has established the current limit setpoint.

Outputs. . . Display (Figure 1)
A blue, 4-digit, vacuum fluorescent display and a "Display Advance" push-button (9) provide access to four specific types of operator's information:

1) Operating Mode, 2) Diagnostic Code,
3) Setpoints, 4) Measured Temperatures

The "Display Advance" push-button simply scrolls through each entry of the operator's display menu sequentially as the button is pressed. A blank display signifies the end of the menu. To go to the top of the menu, press the push-button once.

Operating Mode. . . The first of the three digits is a code prefix, telling which of the eight operating mode menu items is indicated. Table 1 shows the eight code prefixes and their meanings.

Table 1

Code Prefix	Description
A	Operating Mode
b	Last Diagnostic
C	Chilled Water Setpoint
d	Current Limit Setpoint
E	Entering Chilled Water Temp
F	Leaving Chilled Water Temp
H	Entering Condenser Water Temp
J	Leaving Condenser Water Temp

The last two digits of the display indicate which specific operating mode, diagnostic, setpoint or temperature exists, as defined by the prefix. Table 2 shows the menu of operating modes (Prefix "A").

Table 2

Last 2 Digits	Description of Operating Mode
Blank	Power Off
0	Standby/Reset
1	Auto (Local Or Remote)
9	Free Cooling
70	Restart Inhibit
71	Establish Cond Water Flow
72	Start
74	Run: Normal
[1]75	Run: Current Limit
[2]76	Run: Condenser Limit
[3]77	Run: Evaporator Limit
[4]78	Run: Surge Condition
79	Posts-Lube
88	Reset

For example:

[1] As the current limit setpoint is approached, the UCM restricts further inlet guide vane opening.

[2] (Optional) As the condenser pressure limit setpoint is reached, the UCM restricts additional compressor loading to avoid high condenser pressure shut down. In this operating mode, a "head relief request" (optional relay) is initiated.

[3] Further opening of the inlet vanes is restricted to avoid a unit shutdown on low evaporator refrigerant temperature.

[4] (Optional) Compressor loading is suspended and a "head relief request" (optional relay) is initiated. An automatic CenTraVac shutdown will occur if the unit remains in surge for a 15 minute period.

Diagnostic Codes. . . The "Last Diagnostic" codes (Prefix b) are listed in the Appendix. Diagnostics occur only when an abnormal CenTraVac shutdown occurs. If the UCM detects a diagnostic condition, the display alternately flashes between the diagnostic code and the operating code. The "Last Diagnostic" code is erased when the "chiller switch" is placed in the "Standby/Reset" position and then in one of the "Auto" modes. Advancing past the "Last Diagnostic Code" entry in the menu automatically clears the code registered there from memory.

Codes prefixed by a "C" or "d" are followed by the corresponding setpoint value, local or remote, as applicable.

"E", "F", "H" and "J" code prefixes are followed by an actual measurement of the specific system parameter. If the particular sensor is not installed and connected to the control panel, the display will show "----".

Note: The display is redefined to a "Serviceman's Menu" by placing the vane control switch in the "hold" position. Refer to "Operation-Maintenance CVHE-M-3" for instructions on the use of this menu.

Outputs. . . Gages And Meters (Figure 2)

1. Low Oil Pressure. . . This gage monitors the oil pressure inside the oil tank reservoir. Since this reservoir is vented to compressor suction, the Low Oil Pressure should be very close to evaporator pressure.

2. High Oil Pressure. . . This gage measures the pressure in the oil supply line to the compressor bearings. The differential between this pressure and the "Low Oil Pressure" is the net oil pressure.

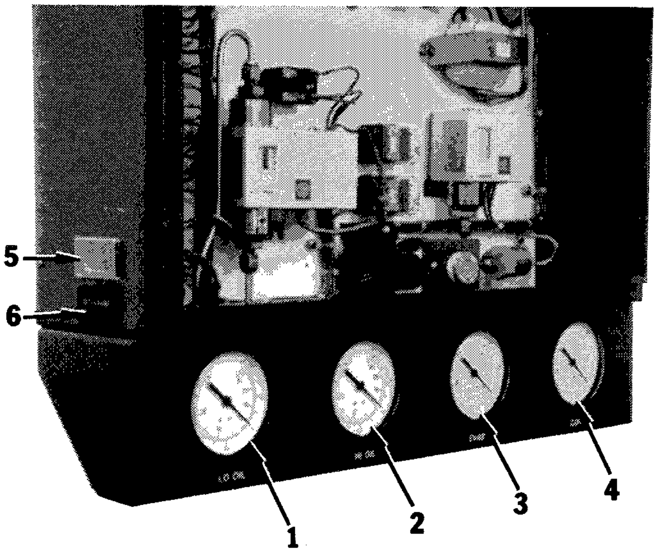


Figure 2

3. Evaporator Pressure. . . This gage indicates the refrigerant pressure in the evaporator.

4. Condenser Pressure. . . This gage indicates the refrigerant pressure in the condenser.

5. Hour Meter. . . This meter indicates the accumulated hours of chiller operation. It will record a maximum of 99,999.9 hours, at which point it restarts at zero hours. It is not resettable.

6. Start Meter. . . This meter displays the accumulated number of compressor starts that have been attempted. It will record 99,999 starts before restarting at zero. It, too, is not resettable.

This completes a description of the operator-machine interface portion of the CenTraVac control panel. Normal chiller operation does not require the panel door to be opened. However, there are a number of important control elements inside the panel.

CVHE safety and operating controls are partitioned into 2 major sections: the Unit Control Module (UCM) and the "non-UCM" devices described below.

Non-UCM Devices (Figure 3)

Condenser High Pressure Switch (1S1). . . . This safety control opens when it detects a condenser refrigerant pressure that exceeds its setting. A chiller shutdown caused by this control produces a latching diagnostic (code "b F5") requiring manual reset. The cutout pressure setting of this control is not automatically coordinated with the setting of the optional "Condenser Limit Control", page 15.

Differential (oil) Pressure Switch (1S2). . . This operating control senses the "high" and "low" oil pressures. See table 3 for control values.

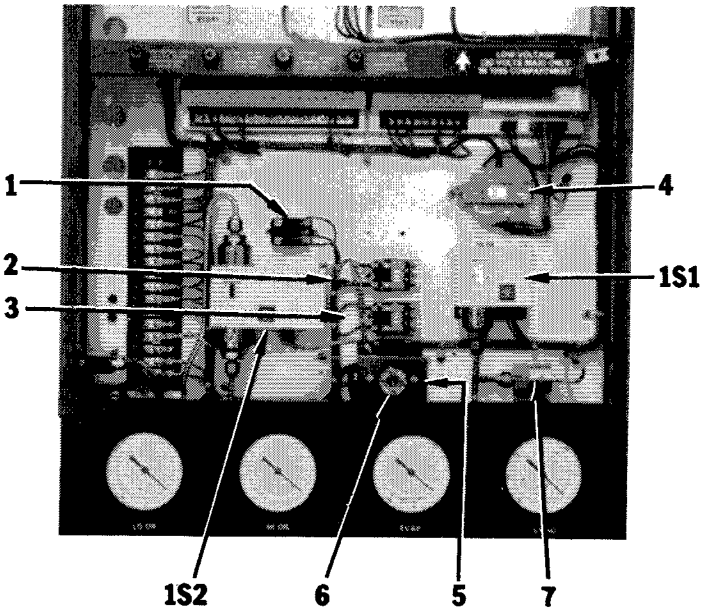


Figure 3

Output Relays. . .

1. 1K8. Oil pump starter.
2. 1K16. Chilled water pump relay.
3. 1K17. Condenser water pump relay.

K15. (Optional) Hot gas bypass relay.

Other Electrical Components. . .

4. Control Power Transformer (1T1).
5. Oil Pump Capacitor (1C1).
6. Oil Pump Fuse (1F1).
7. (Optional) Condenser pressure transducer.

Table 3

Safety Control Unit Cutouts		Control Trip Point	Diagnostic Code
Motor Winding Temperature Run Inhibit		265 ± 15 F	b E7
High Oil Temperature Run Inhibit		180 ± 2 F	b F4
High Bearing Temperature Run Inhibit (Optional)		180 ± 2 F	b EA b Eb
Differential Oil Pressure Switch	Opens	9 psig diff.	b E8 or b F2
	Closes	11.5 to 15 psig diff.*	
High Condenser Pressure Cutout Switch	Std. units	15 ± 1 psig	bF5
	ASME units	25 ± 1 psig	
Low Water Temperature Cutout, Lvg. Chilled Water		35 ± 1 F	None. . . auto reset

*Switch has non-adjustable 2.5 to 6 psi differential range.

Hardware

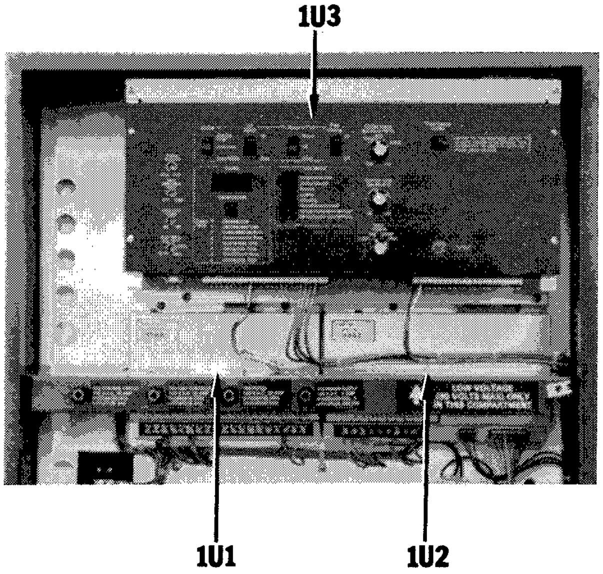


Figure 4

UCM (Figure 4)
The Unit Control Module is actually a series of microprocessor based sub-assemblies that handle most of the safety and control functions. Sub-assembly sections are:

Relay/Output Module (1U1). . . This module contains the relays that interface panel microelectronics with specific electrical devices outside the panel. Its terminal strip identification is (1TB1).

- Compressor Inlet Vane Operator (4B2): Open (1U1Q7), Close (1U1Q8).
- Condenser Water Pump Relay (1U1K6).
- Purge Unit Relay (1U1K9).
- (Optional) Head Relief Request Relay (1U1K3).
- (Optional) Alarm Relay (1U1K4).
- (Optional) Free Cooling and Auxiliary Free Cooling Relays (1U1K1 and 1U1K2).

Power Supply/Output Module (1U2). . . This module contains the power supply for microelectronic circuits and relays. Further, it provides relay contact closures to interface with specific devices outside the panel. Its terminal strip identification is (1TB2).

- Reset Relay (1U2K1).
- Stop Relay (1U2K2).
- Overload Relay (1U2K3).
- Compressor Start Relay (1U2K4).
- Starter Transition Relay (1U2K5).
- Oil Heater Relay (1U2K6).
- Oil Pump Relay (1U2K7).

Micro Module (1U3). . . This module houses the microprocessor that contains all control algorithms for the CenTraVac control system. It accepts a variety of sensor inputs through terminal strips (1TB3, 1TB4 and 1TB6).

- Leaving Chilled Water Temperature (4RT1).
- (Optional) Entering Chilled Water Temperature (4RT2).
- (Optional) Entering Condenser Water Temperature (4RT3).
- (Optional) Leaving Condenser Water Temperature (4RT4).
- Evaporator Refrigerant Temperature (4RT5).
- (Optional) Ambient (air) Temperature (4RT6).
- Chilled Water Flow (1K16).
- Condenser Water Flow (1K17).
- Inlet Vanes Closed (4B2).
- Differential Oil Pressure Switch (1S2).
- (Optional) Running External Interlock (5S4).
- Transition Complete (2K2).
- Oil Temperature (4RT7).
- Motor Winding Temperature (4B1R2, 4B1R3 and 4B1R4).
- (Optional) Bearing Temperature #1 (4RT8).
- (Optional) Bearing Temperature #2 (4RT9).
- Motor Current (from current transformer 2T5).
- Motor Current (from current transformer 2T6).
- Motor Current (from current transformer 2T7).

Chilled Water Reset Interface Module (1U4). . . This optional module is mounted in the control panel when the Chilled Water Reset Interface option is installed. It accepts one input (4 to 20 ma or 0 to 10 vdc reset signal) and is connected to the 1U3 module. Its terminal strip designation is TS1.

Based on these inputs, this module performs four basic functions:

1. It controls the leaving chilled water temperature in response to the setpoint by repositioning the compressor inlet guide vanes.

4. It executes start and stop sequences.

In addition, this module can (optionally) perform either of two mutually exclusive control options:

- System Controller Interface (SCI)... This option provides a proprietary interface with a higher level control authority "Trane System Control Panel". This system is described more fully, beginning on page 23.
- Chilled Water Reset (CWR)... This option enables the UCM to reset the chilled water temperature setpoint based on load (entering chilled water temperature) or ambient air temperature.

System Operation

The control logic that governs the CenTraVac chiller system takes the form of algorithms that reside in UCM memory. Two references embellish the written explanations. They are Figures 6 (a time-line of sequential events) and 5 (a line wiring diagram).

Power Supply. . . With the power supply disconnect switch or circuit breaker (2CB1) closed, 120 volt power is provided through control power transformer (2T4) and a 30-amp starter panel fuse (2F4) to terminal 1TB5-1. From this point, control voltage is available through:

Fuse (1F2), supplying power to the micro module (1U3), starter control, oil heater, and secondary transformer 1T1 circuits.

Fuse (1F3), supplying power to the oil pump and inlet vane operator circuits.

Fuse (1F4), supplying power to the purge control system.

The 1F2 branch circuit directs power to five separate subcircuits:

1. The micro module (1U3). The relay output module (1U2) and the power supply module (1U1) all receive power through another fuse (1F5) and the power supply transformer (1T1).

2. The oil sump heater (4HR1) is energized through the normally- open K6 contacts of the power supply output module (1U2). Temperature sensor (4RT7), located in the oil sump, controls K6 to keep the oil temperature between 140F and 145F.

3. Chilled water flow switch (5S2) circuit. . . Closure of this switch and the chilled water pump electrical interlock (5K1) energizes relay 1K16, giving the micro module an indication that chilled water flow does exist.

4. Condenser water flow interlock (5S3) circuit. . . Closure of this switch and the condenser water pump electrical interlock (5K2) energizes relay 1K17, giving the micro module an indication that condenser water flow does exist.

5. Starter Control circuit. . . The state of relay contacts K1 (reset), K2 (stop) and K3 (overload) are determined by logic executed in the micro (1U3). When they appear "closed", control voltage passes to the compressor "start" relay (K4). If all preconditions for start-up are met, the micro sends a signal to the power supply output module (1U2) to close the K4 contacts. A "start" signal is passed along to the compressor motor starter relay (2K5). Simultaneously, control voltage flows to the start counter (1M2) and the hour meter (1M1).

Starting Sequence. . . The following paragraphs describe the starting sequence for a conventional wye-delta, closed transition type starter, commonly used on CenTraVac compressor motors.

Relay 2K5 has two sets of N.O. contacts. The first set (Line 18) closes to lock the starter relay into the control circuit around the K4 contacts. The second (Line 19) enables control voltage to flow through the N.C. contacts of 2K2 (starter start, 1M) and 2K4 (starter transition, 1A) to the coil of starter contactor 2K3 (starter star, S).

When star contactor (2K3) energizes, its N.O. auxiliary contacts (Line 21) close, allowing control voltage to pass to the coil of starter contactor 2K1 (starter start, 1M). Auxiliary contacts lock 2K1 in, around the auxiliary 2K3 contacts. Power is now supplied to the compressor motor (4B1) in the Wye, or Star, configuration through the 2K3 and 2K1 contactors.

As the compressor accelerates, compressor motor current decreases. When motor current falls to 85% of the motor RLA setting, the micro sends a signal to (1U2) to close the N.O. contacts of transition relay K5. This energizes the coil of transition contactor (2K4) and causes its N.C. set of auxiliary contacts (Line 19) to open.

With the star contactor (2K3) now open, 2K3 drops out and its N.C. auxiliary contacts (Line 22) reclose, allowing control power to reach the coil of starter contactor (2K2) (starter run, 2M). Contactor 2K2 is locked in by a set of auxiliary contacts (Line 23) around auxiliary contacts on 2K3 and 2K1 (Lines 21 and 22). Further, an auxiliary set of N.C. 2K2 contacts open (Line 19) to interrupt control voltage to the transition contactor 2K4.

Within the starter itself, contactors "S" and "2M" are physically prevented from closing simultaneously. This is in addition to the foregoing electrical interlocks.

The compressor is now operating in the normal "run" mode. It will continue to operate this way until the "net state" of the K1, K2 and K3 contacts in (1U2) "open". At this point, voltage to the starter relay (2K5) disappears and starter relays are de-energized.

Stopping The Compressor. . . Any of the following conditions will cause the "net state" of the K1, K2 and K3 string of contacts in module 1U2 to be open, stopping the compressor:

1. Chiller switch is placed in "Standby/Reset",

2. A latching or non-latching diagnostic is detected by the UCM, or

3. Chilled water load (by virtue of a decrease in return water temperature) is insufficient to keep the chiller operating. The setpoint for this control is determined by adjusting the "differential to start" (a serviceman's control setting on the control panel). Table 4 shows recommended "differential to start" settings.

Table 4 — Recommended Differential to Start Settings

Chiller Delta T Degrees F	Setting Deg. F	Degrees Below Setpoint Where Chiller Shutdown Occurs (Exit CHW Temp)
4 or less	2.0	2.0
5 or 6	3.0	2.0
7 or 8	4.0	2.0
9 or 10	5.0	2.0
11 or 12	6.0	2.0
13 or 14	7.0	2.0
15 or 16	8.0	2.4
17 or 18	9.0	3.2
19 or more	10.0	4.0

As an example, consider a chilled water system designed for a full load delta-T of 12 F and a supply water temperature of 44F. By setting the temperature controller at 44F and the "differential to start" at 6F, the chiller will start when the supply and return temperatures rise to 50F. While this may seem to represent a 50% chiller load, it probably does not. The 50F return temperature occurs only because the chiller is not running. As soon as the supply temperature is decreased to 44F, the return will also decrease. The chiller will continue to run, controlling the supply water to 44F, until its minimum capacity exceeds the real system load. At this point, both the supply and return temperatures will steadily fall, until the return temperature drops 2.0F below the setpoint of 44F. At 42F the chiller will automatically stop and remain stopped until the system water again warms to 50F.

Fuse 1F3 Branch Circuit.

Oil Pump Circuit...The 1F3 branch circuit sends 120 volt control power through fuse 1F1 to the oil pump motor (4B3). Fuse 1F1 protects the oil pump motor from overcurrent conditions. Parallel contacts of the compressor motor starter interlock (2K1) and the oil pump relay (K7 in 1U2) keep oil pump motor starter (4B3) energized. While the location of K7 is 1U2, its status is controlled by the micro (1U3).

The oil pump motor is a single-phase capacitor start motor. The capacitor is engaged when its high starting current flows through current sensing relay (1K8). The "start" winding provides additional starting torque. As the motor accelerates, its lower current drops out the starting relay (1K8), and the motor runs on its "run" windings only.

As long as the micro calls for oil pump operation, it will run. Further, parallel contacts from the compressor motor starter (2K1) will keep the oil pump operating any time the compressor motor is running, whatever the cause. Oil pump operation ceases only when both K7 and 2K1 open.

Inlet Vane Actuator Circuit...120 volt power enters the inlet vane actuator motor (4B2) at terminal 2. This motor is highly accurate in positioning the inlet vanes. It runs either to the "open" or "closed" position. Therefore, small, precision movements are accomplished by "pulsing" the motor.

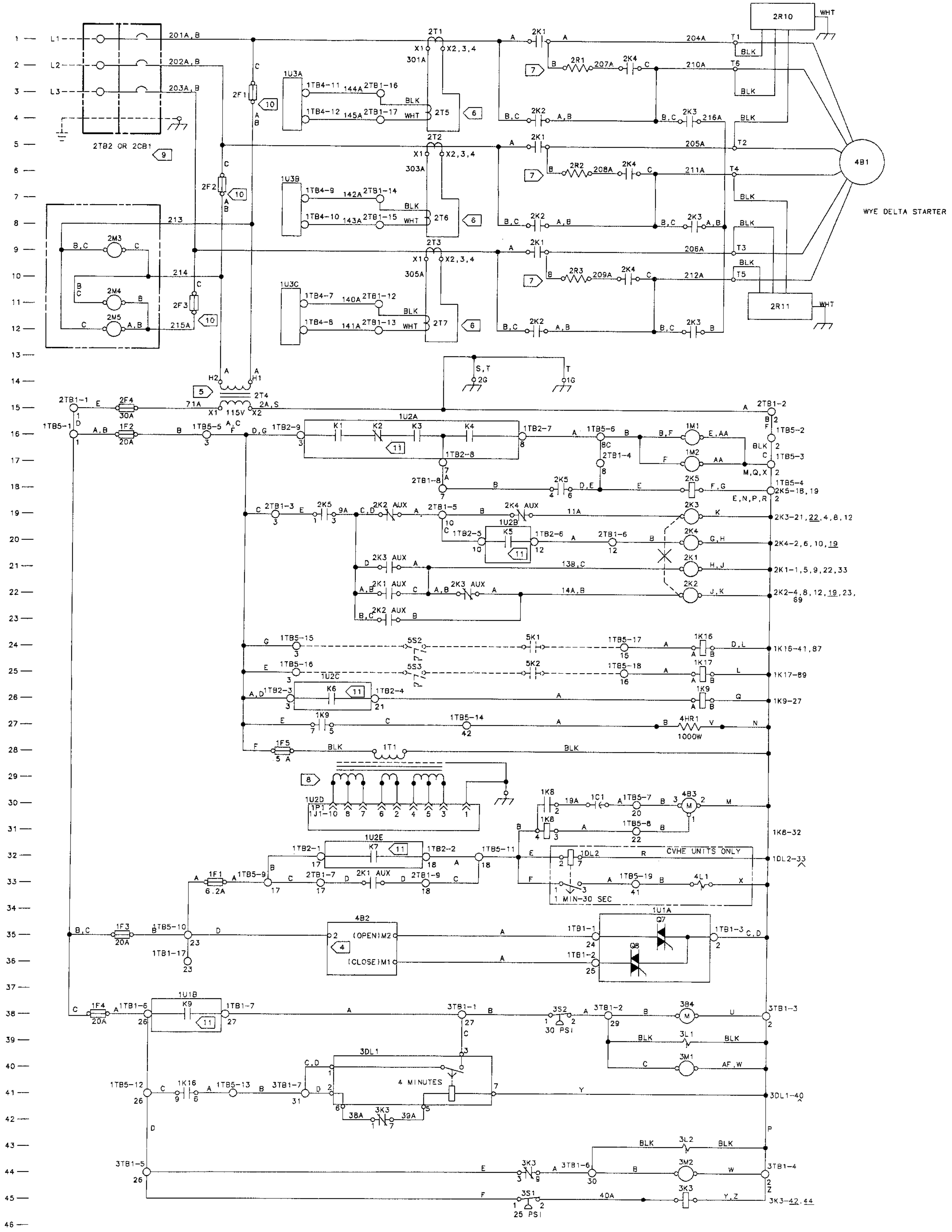
Pulsing signals are generated by Triac switches (Q7 and Q8) located in the relay output module (1U1). Appearing like relays, Q7 and Q8 are controlled by the micro (1U3).

Fuse 1F4 Branch Circuit.

Purge System Circuit...The purge system automatically rejects impurities that may leak into the CenTraVac. This includes both condensible (mainly water) and non-condensible (mainly air) impurities. Since one is usually not present without the other, the need for purging is signalled by an increase in purge drum pressure, after a brief period of purge compressor (3B4) operation.

Automatic purge operation involves periodic timed purge compressor running. If no impurities are found, the purge compressor will run for 5 minutes out of every 2 hour period that chilled water flow is available and the chiller is in one of the two "auto" positions. The presence of impurities elevates the purge drum pressure and extends running time through the action of timer (3DL1) and pressure switch (3S1).

A more complete explanation of manual and automatic purge unit operation is found in "Operation/Maintenance CVHE-M-3".


L1
L2
L3
2TB2 OR 2CB1
9
201A,B
202A,B
203A,B
2F1
2F2
2F3
10
2T1
2T2
2T3
X1
X2,3,4
301A
303A
305A
1U3A
1U3B
1U3C
2T5
2T6
2T7
6
BLK
WHT
2K1
2K2
2K3
2K4
2R1
2R2
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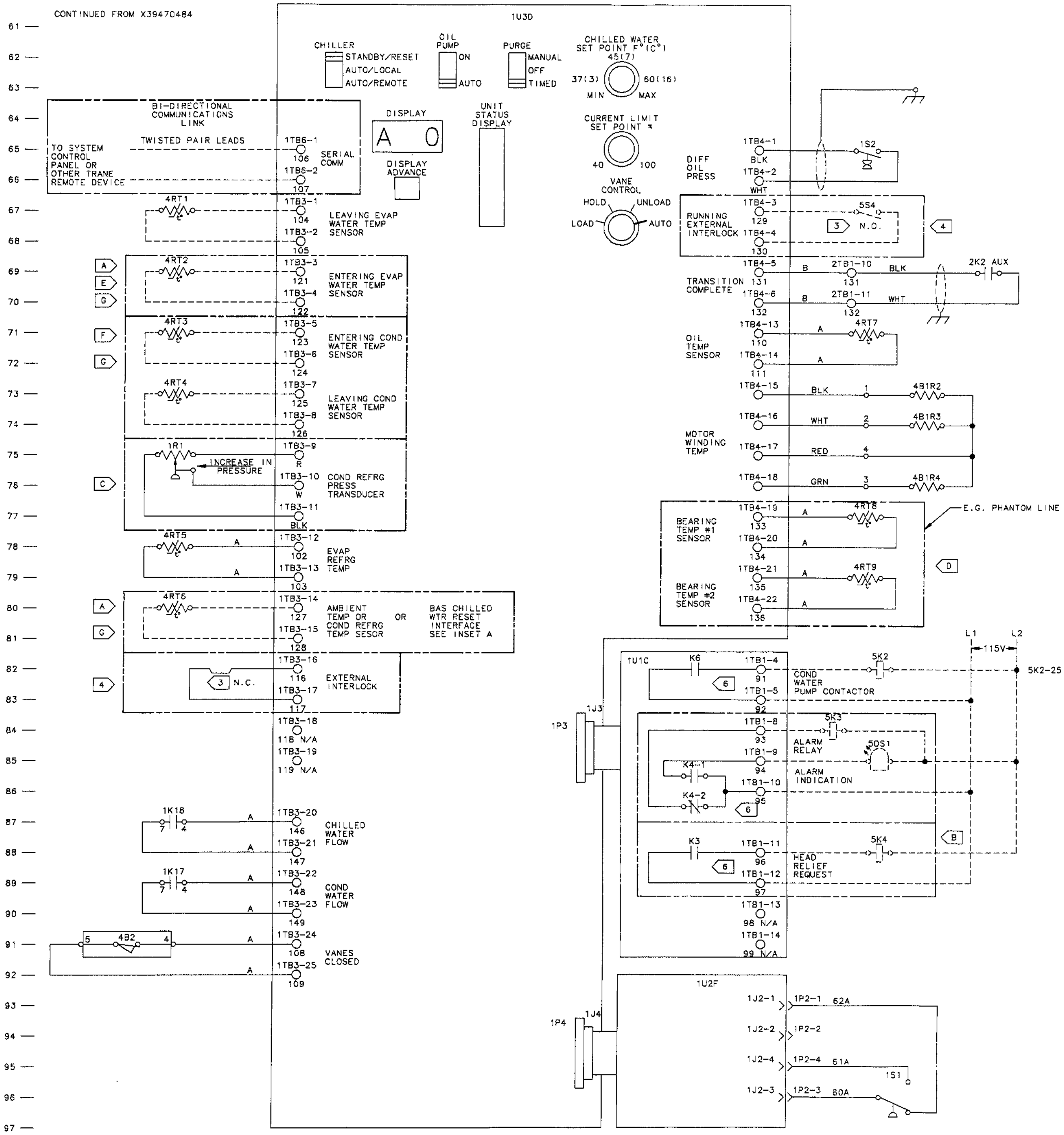
T1
T2
T3
T4
T5
T6
2R10
2R11
4B1
WYE DELTA STARTER
2M3
2M4
2M5
213
214
215A
2T4
115V
5
2G
1G
2TB1-1
2F4
30A
1F2
20A
1TB5-1
1U2A
K1
K2
K3
K4
11
1M1
1M2
2K5
2K3-21,22,4,8,12
2K4-2,6,10,19
2K1-1,5,9,22,33
2K2-4,8,12,19,23,69
1U2B
K5
5S2
5S3
5K1
5K2
1K16
1K17
1U2C
K6
1K9
1K16-41,87
1K17-89
1K9-27
4HR1
1000W
1F5
.5 A
1T1
8
1U2D
1K8
1C1
4B3
1K8-32
1U2E
K7
1DL2
CVHE UNITS ONLY
1DL2-33
1 MIN-30 SEC
4L1
1F1
6.2A
1F3
4B2
(OPEN)M2
(CLOSE)M1
4
1U1A
Q7
Q8
1U1B
K9
1F4
3S2
30 PSI
3B4
3L1
3M1
3DL1
4 MINUTES
3K3
38A
39A
3DL1-40
3L2
3M2
3S1
25 PSI
40A
3K3-42,44

Figure 5



	LEGEND	
DEVICE DESIGNATION	DESCRIPTION	LINE NUMBER
1C1	CAPACITOR, OIL PUMP	32
1DL2	VENT LINE INTERV. TIMER	32
1F1	FUSE, OIL PUMP	33
1F2-5	BRANCH CIRCUIT FUSE	16,35, 28,38
1J1-4/1P1-4	POST HEADER POWER SUPPLY	31,85,94
1K8	OIL PUMP STARTER RELAY	33
1K9	OIL TANK HTR RELAY	26
1K16	CWD WTR PUMP RELAY	24
1K17	COND WTR PUMP RELAY	25
1M1	HOUR METER	16
1M2	START METER	17
1R1	RESISTOR PRESS TRANSDUCER	75
1S1	COND. HIGH PRESS SWITCH	95
1S2	OIL PRESS SWITCH	65
1T1	POWER SUPPLY TRANSFORMER	28
1TB1	TERM BLOCK REL OUTPUT	
1TB2	TERM BLOCK POWER SPLY	
1TB3	TERM BLOCK MICRO-MOD INPUT	
1TB4	TERM BLOCK MICRO-MOD INPUT	
1TB5	TERM BLOCK CONTROL PANEL	
1TB6	TERM BLOCK MICRO-MOD INPUT	65,66
1U1A-C	RELAY OUTPUT MODULE	SHEET 2
1U1K3	HEAD RELIEF RELAY	89
1U1K4	ALARM RELAY *	85
1U1K6	COND WATER PUMP RELAY	82
1U1K9	PURGE RELAY	38
1U1Q7	VANES OPEN (TRIAC)	35
1U1Q8	VANES CLOSED (TRIAC)	36
1U2A-F	POWER SUPPLY OUTPUT MOD	SHEET 2
1U2K1	RESET RELAY	16
1U2K2	STOP RELAY	16
1U2K3	OVERLOAD RELAY	16
1U2K4	COMPR.START RELAY	16
1U2K5	COMPR.TRANSITION RELAY	20
1U2K6	OIL HEATER RELAY	27
1U2K7	OIL PUMP RELAY	32
1U3A-D	MICRO MODULE	SHEET 2
1U4	BAS CHILLED WTR RESET	94
2CB1	STARTER CIRCUIT BREAKER	1,2,3
2F1,2,3	PRIMARY STARTER FUSE	3,6,11
2K1	START CONTACTOR	21
2K2	RUN CONTACTOR	22
2K3	SHORTING CONTACTOR	19
2K4	TRANSITION CONTACTOR	20
2K5	PILOT RELAY	18
2M3,4,5	VOLT METER	9,11,12
2M6,7,8	AMPMETER	49,53,57
2R1-9	TRANSITION RESISTOR	2,6,10
2R10,11	SURGE ARRESTER	1,10
2T1-3	CURRENT TRANSFORMERS	1,5,9
2T4	CONTROL POWER TRANSFORMER	14
2T5,6,7	CURRENT TRANSFORMERS	4,7,11
2TB1	CONTROL TERMINAL BLOCK	
2TB2	LINE TERMINAL BLOCK	1,2,3
3B4	PURGE MOTOR	36
3DL1	PURGE RUN DELAY TIMER	41
3K3	PURGE SWITCH RELAY	45
3L1	PURGE SOLENOID VALVE	39
3L2	PURGE BLEED VALVE	43
3M1	PURGE HOUR METER	40
3M2	PURGE CYCLE COUNTER	44
3S1	PRESS SWITCH EXTEND RUN	45
3S2	PRESS SWITCH SAFETY	38
3TB1	PURGE TERMINAL BLOCK	
4B1	COMPRESSOR MOTOR	5
4B1R2,3,4	MOTOR WINDING TEMP SENSOR	69,71,73
4B2	VANE ACTUATOR MOTOR	35
4B3	OIL PUMP MOTOR	32
4HR1	OIL TANK HEATER	27
4L1	VENT LINE SOLENOID	33
4RT1-9	THERMISTOR	69,67,70 73,77,80
5DS1	ALARM INDICATION	85
5K1	CHWD WATER PUMP CONT. AUX	N/A
5K2	COND WATER PUMP CONT. AUX	82
5K3	ALARM RELAY	84
5K4	HEAD RELIEF REQUEST CONT.	88
5S2	CHWD WATER FLOW SWITCH	24
5S3	COND WATER FLOW SWITCH	25
5S4	INTERLOCK SWITCH	67

Figure 5 (cont.)

Sequence Of Operation

Figure 6 displays a "Time-Line" sequence of operation. Description of Figure 6:

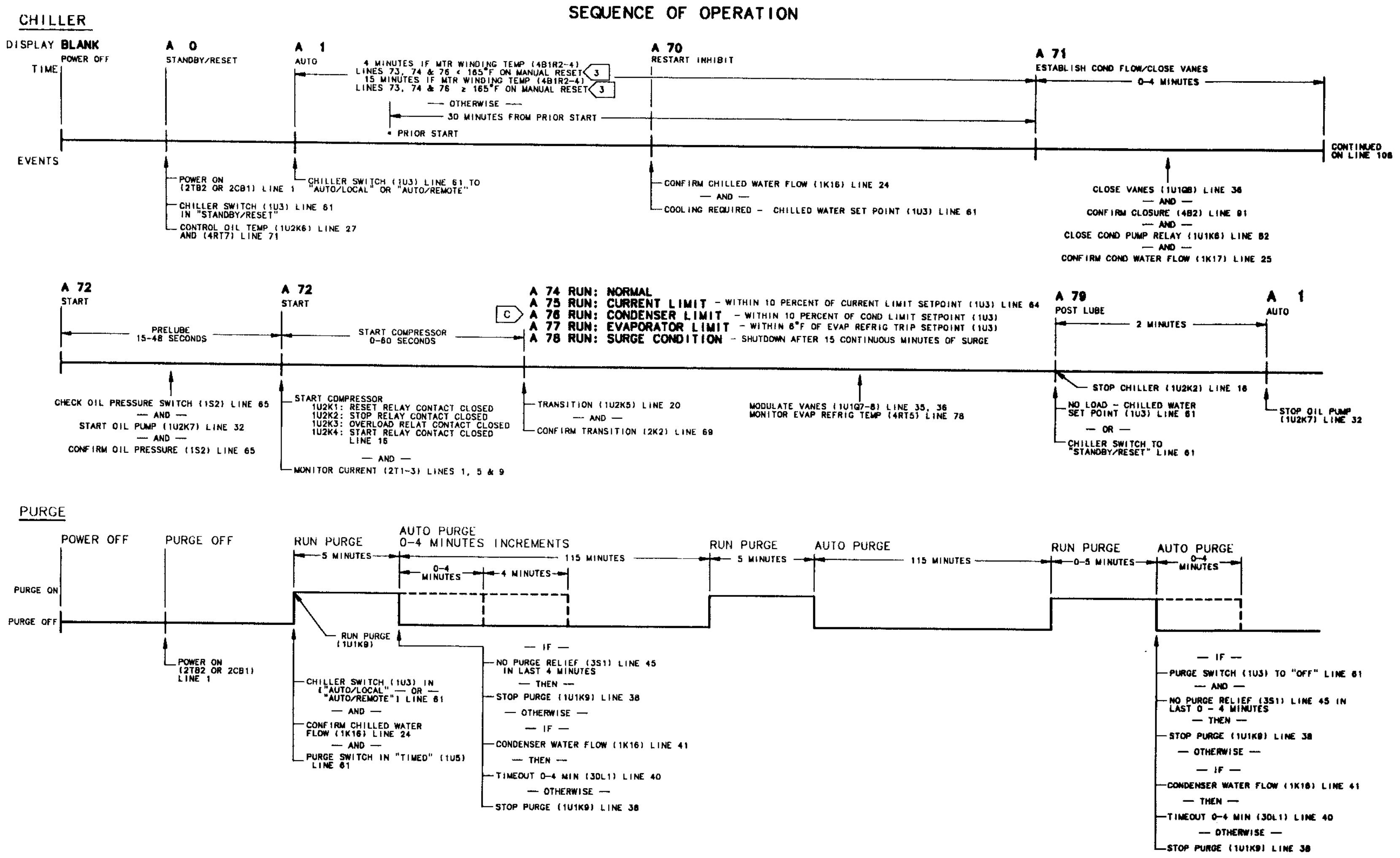


Figure 6

DISPLAY	DIAGNOSTIC	INTERPRETATION	TIME
BLANK	POWER OFF		
00	STANDBY/RESET	Power on. System is reset.	
01	AUTO	Chiller switch in auto/local or auto/remote. System is armed but cooling not required.	
70	RESTART INHIBIT	CVHE held off. Confirm chilled water flow.	Delay is: 4 min. if WT < 165F, 15 min. if WT > 165F, or 30 min. from prior start.*
71	ESTAB COND WTR FLOW	Output signal to run condenser water pump and to close inlet vanes. Confirm CDW flow and closure of inlet vanes.	Wait up to 4 min. for confirmations.
72	START	Prelube. Start oil pump motor. Confirm oil pressure.	Wait from 15 to 48 sec. to establish oil pressure.
72	START	Start compressor motor. Relays closed: (1U2K1) Reset (1U2K2) Stop (1U2K3) Overload (1U2K4) Start Monitor motor current.	Wait up to 60 sec. to accelerate motor.
74	RUN: NORMAL	Initiate compressor motor starter transition to "run". Confirm transition. Modulate inlet vanes.	
75	RUN: CURRENT LIMIT	Same as 74, plus inlet vane position limited by motor current.	
76	RUN: COND LIMIT	Same as 74, plus inlet vane position limited by approach to condenser pressure cutout setting.	
77	RUN: EVAP LIMIT	Same as 74, plus inlet vane position limited by approach to evaporator temperature cutout setting.	
78	RUN: SURGE CONDITION	Same as 74, plus head pressure relief relay energized by compressor surge condition.	
79	POST LUBE	Compressor stopped by: no load; chiller switch set to "reset" position; or (optional) free-cooling switch set to "on".	Oil pump is run 2 min. in post lube.
01	AUTO	Stop oil pump. Chiller is armed. Chiller shutdown on loss of cooling required.	

*After chiller switch is toggled to AUTO, the 70 display is skipped if the machine has been in the 01 condition, without cooling required, long enough to satisfy the timers.

CenTraVac System Control

Capacity Control

CenTraVac capacity is controlled to match chilled water system demand through repositioning the compressor inlet guide vanes. A variation in leaving chilled water temperature indicates a mismatch between chiller capacity and system load. Therefore, leaving chilled water temperature is the sensed variable for the capacity control system.

Control algorithms reside in the micro module (1U3). Any deviation from chilled water temperature set point creates a response via the condition of Triacs (1U1Q7 and 1U1Q8). The exact control response is calculated in the micro. Proportional, integral and derivative characteristics are incorporated in this controller. Consequently, the CenTraVac can be applied in a wide variety of comfort and process chilled water systems.

Control Accuracy.
Control accuracy depends, to some extent, on the "control gain" setting. This serviceman's setting (under the covered portion of the front panel) increases the speed of response as well as its sensitivity. The purpose of providing a "control gain" adjustment is to allow the chiller's response dynamics to be matched to the dynamic characteristics of the system.

Systems consisting of extremely short water loops respond quickly. They require fast response from the temperature control system. However, fast responding controls are usually more sensitive and prone to instability. There is no advantage in applying fast response controls to a system with slow dynamics. With the proper control gain setting, the CenTraVac temperature control system is designed to hold the leaving chilled water temperature within 1F of the setpoint, if the system delta-T is 15F or less. Accuracy is within 2F if the system delta-T is above 15F.

Load Limiting.
Compressor loads are determined by chilled water system conditions. Yet, compressor motor capacity is finite. Somehow, the control system must be able to limit compressor loads so as not to overload the compressor motor.

Compressor load limiting is accomplished by repositioning the inlet vanes whenever a pre-determined motor load is reached. Motor load is sensed by three current transformers located in the motor starter. If the micro senses that motor current is approaching the current limit, it will direct the inlet vanes to "hold" or "close", depending on how imminent the approach is.

The load limiting setpoint is adjusted in two ways. The primary setting (100%) is set by the service engineer. It is based on the RLA of the CenTraVac motor. The "Current Limit Setpoint %" (see "Inputs", item 6, page 3) cannot exceed 100%, but can be set to any lesser percentage, down to 40%. Since the measured variable is motor current, the percentage value refers to current. . . not motor or chiller load. (Motor current is not linearly proportional to either motor or chiller load).

Other Variables That Alter Inlet Vane Position.
Algorithms in the micro recognize other operating and safety conditions that have a bearing on vane position.

Motor Overload Current Trip. . . Separate calculations are made in the micro to evaluate the proximity to the motor overload current trip setting. As this setting is approached, inlet vane opening is inhibited. Further approach causes an "unload" command. Failing to arrest approach to the trip setting, the micro will initiate a latching diagnostic, overload trip (b Ec).

Evaporator Refrigerant Temperature. . . A temperature sensor (4RT5) in the evaporator provides information to the micro that allows it to determine an approach to the cutout temperature setting. When such an approach is discovered, inlet vanes are given a "hold" or "close" command, depending on the speed and magnitude of the approach.

Condenser Refrigerant Pressure (Optional). . . Similarly, an approach to the refrigerant pressure (as sensed by the optional pressure sensor) limit setting, will result in micro outputs that override inlet vane repositioning instructions.

Motor Protection

The compressor motor represents the costliest part of a CenTraVac. Its protection is of primary concern. Algorithms in the micro guard against the effects of the abberations listed below. Table 4 shows the diagnostic, its code and its reset mode.

Table 4

Diagnostic Description	Reset Mode	Code
Motor current overload	Manual	b Ec
Momentary power loss	Automatic	b E2
Extended power loss	Automatic	b d9
Low voltage	Automatic	b d9
Phase imbalance	Manual	b E3
Phase loss	Manual	b E4
Phase reversal	Manual	b E5
High motor temperature	Manual	b E7
Max. accelerating time	Manual	b EE
Transition	Manual	b F0

Motor Current Overload. . .3-phase motor current is monitored continuously. An explanation of the algorithm used during motor starting appears on page 8. Shortly after the micro receives confirmation of a "compressor run" signal, running current is monitored. Any current over 107% of the setting for motor RLA will result in an overload trip. The "inverse-time" relationship above 107% RLA integrates current and time such that a steady 107% current will trip in 20 seconds. Any current exceeding 140% RLA will result in an overload trip in 1 second.

Momentary Power Loss. . .The damage potential of momentary power loss (6 to 30 cycles) is well documented. When the micro contacts 1U2K1 (reset), 1U2K2 (stop) and 1U2K3 (overload), Figure 5, are closed and the motor current falls to 15 percent of RLA, this simultaneous event can only occur when line voltage is interrupted.

Interruptions of less than 30 cycles causes an E2 diagnostic (momentary power loss), greater than 30 cycles a d9 (extended power loss). Both are non-latching (automatic reset) diagnostics.

Low voltage. . .Motors can be damaged by continuous low line voltage when the combination of motor load and low voltage results in higher than RLA current. CenTraVac motors are protected from overcurrent by the load limiting system and the overload trip.

Additionally, low voltage can produce unexpected and unpredictable operation of relay coils. The micro, by sensing control power voltage, detects this condition and issues the non-latching diagnostic (b d9), which is the same as an extended power loss.

Phase Loss or Imbalance. . .The loss or imbalance of any of the three electrical phases causes the remaining motor current to increase. Since the three phases are monitored independently, unbalanced phase currents, or zero phase currents, produce a latching diagnostic.

Phase Reversal. . .While the CenTraVac is not mechanically harmed by operation in the reverse direction, its cooling performance is grossly effected. Phase reversal is detected by the micro and results in a separate latching diagnostic.

High Motor Temperature. . .Motor stator winding resistance temperature detectors provide the micro with this information. It is used in two ways. First, a winding temperature under 165F allows a normal "start inhibit" time of 4 minutes after the chiller switch is placed in either of the "auto" positions. A winding temperature of 165F or above causes a "start inhibit" time of 15 minutes.

Second, a latching diagnostic indicating high motor temperature occurs if the detectors encounter a winding temperature of 265F.

Maximum Acceleration Time. . .Should motor starting torque not overcome accelerating torque in a specified time, the micro will issue a trip command and a latching diagnostic. This is detected by measuring the time interval between the signal to start and a reduction in motor current to less than 85% of RLA.

Transition. . .If transition from "start" to "run" is not completed within two seconds of its initiation, a trip signal and diagnostic are generated by the micro.

Control Options

The standard CenTraVac control system can be equipped with a variety of optional controls that perform specific "value-added" functions.

1. Relay Package. . .This option consists of two relays. . .an "alarm" relay and a "head relief request" relay.

Dry contacts of the alarm relay are field-connected between terminals 1TB1-9 and 1TB1-10 (normally open) or 1TB1-8 and 1TB1-10 (normally closed). The "coil" for this relay is powered by the micro through module (1U1). A customer-supplied alarm can be triggered by the alarm relay.

Designed for use with the standard surge protection feature as well as the optional condenser pressure limit control, the head relief request relay is intended to provide a signal for a reduction in entering condenser water temperature. NOTE: This relay is not intended to act as condenser water temperature controller. (Its logic contains no control algorithms which would allow it to perform as a controller). The normally-open relay is field connected between terminals 1TB1-11 and 1TB1-12.

2. Condenser Limit Control. . .This option is designed to prevent "nuisance" trip-outs of the refrigerant high pressure safety control. This option includes a manually adjustable condenser limit potentiometer (1R1), a pressure transducer and associated piping and wiring.

In an attempt to prevent a high pressure trip, this option limits inlet vane opening when the potentiometer setting is approached. If the Relay Package (above) is included, the head relief request relay may also energize to signal further corrective action (such as lowering the condenser water temperature).

3. Bearing Temperature Sensors. . .This option includes sensors 4RT8 and 4RT9 connected to 1TB4-19 & 20, and 1TB4-21 & 22, respectively. Should the motor/compressor bearing temperatures reach or exceed 180 F., the chiller is stopped with latching diagnostic bEA or bEb.

4. Chilled Water Reset. . .This option can be used on applications where design chilled water

temperature may not be needed to meet system part-load conditions. In these cases, the leaving chilled water temperature can be automatically reset upward using this option.

Reset authority tables shown in CenTraVac "Operation and Maintenance Manuals" determine the amount of temperature resetting that will occur. Two reset initiators are possible: a) return chilled water temperature, and b) ambient (outside) air temperature. (See "Generic BAS Chilled Water Reset Interface"', below.)

If return chilled water is the basis of reset, a sensor is installed in the return chilled water piping and its leads are connected to terminals 1TB3-3 & 4. The "Operation and Maintenance Manual" applicable to the specific model CenTraVac contains setup instructions to provide the appropriate amount of temperature reset for any particular application.

If ambient air temperature is used to establish the amount of chilled water temperature reset, an outside air temperature sensor is wired to terminals 1TB3-14 & 15. Care must be taken in the placement of this sensor to avoid "temperature contamination" from sunlight, radiation or atypical airstreams. Commonly, this sensor is placed in the fresh air intake to the building.

5. Generic BAS Chilled Water Reset Interface... This option is used in conjunction with the chilled water reset option. It allows the chilled water setpoint to be reset directly by an external 4-20 ma or 0-10 vdc signal. This option is most frequently used in conjunction with a generic building automation system (BAS) that has the capability of determining an appropriate chilled water setpoint by monitoring the building load requirements.

This option is provided through an additional module (1U4) that is mounted inside the control panel. Reset is only allowed upward from the front panel setpoint and the maximum amount of reset is 20 F. For additional information see the CenTraVac Operation/Maintenance manual CVHE-M-3A.

6. Serial Communications Interface...A serial communications interface option allows the microprocessor module to exchange information with a higher-level control device. A "translator", such as a Trane SCP699, must be used between the UCM and the higher-level control device, typically a TRACER automation device.

Condenser Water Control

The CVHE control system does not control condenser water temperature or flow. In application, some chillers may require some form of condenser water control. There are several to choose from, depending on the need.

Head pressure control...Chillers using an "infinite heat sink", such as a lake, river or supply of ground water, usually need this kind of control. We cannot exert much control over the temperature of natural bodies of water. Therefore, it is common to control flow in such a way as to 1) provide enough water to maintain efficient operation and, 2) limit flow so adequate condenser refrigerant pressure is provided to insure proper operation of various chiller "sub-systems", such as lubrication and motor cooling.

By sensing condenser refrigerant pressure, a simple reverse-acting proportional controller can be used to regulate the position of a water modulating valve located in the leaving condenser water line. The leaving position is used to keep the condenser "full" of water when a drain can act as a siphon. Refrigerant pressure is sensed by tapping into the condenser pressure gage line, taking care to prevent the build-up of a column of liquid refrigerant that may give false pressure indications.

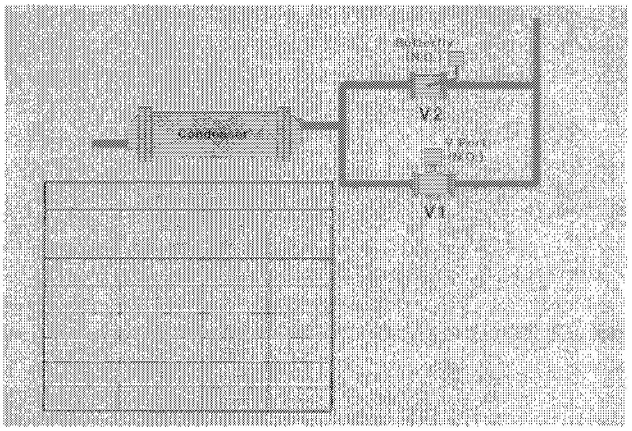


Figure 7

Modulating valve selection also depends on the application. For precision and wide flow variation, V-ported valves are best, although expensive. An alternative to a large V-ported valve can sometimes be found by using a large butterfly valve in parallel with a smaller V-ported valve, as shown in Figure 7. The total control pressure range is split sequentially between the two valves. This allows precise V-port valve control at low flows where hunting can occur, and the large capability of a butterfly valve to pass high volumes.

Application of this concept is not necessarily limited to infinte heat sinks. Head pressure control, by way of flow modulation, can also be applied

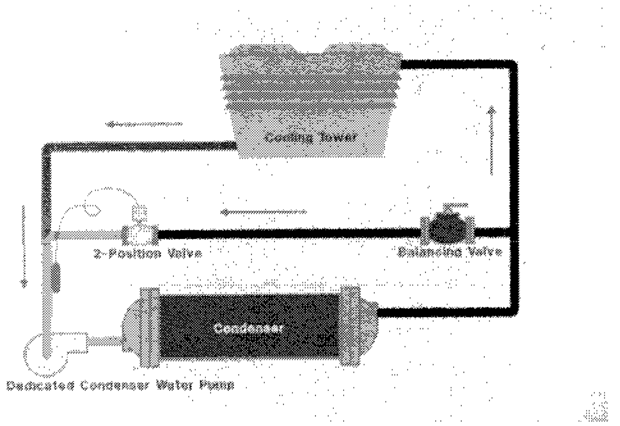


Figure 8

A simple method to assure proper condenser water temperature is shown in Figure 8. This scheme uses the "dedicated pump" concept. Water is recirculated within the condenser loop until it reaches a high limit temperature. At this point, a two-position control valve is closed, preventing recirculation. A balancing valve is used in the recirculation loop to adjust the loop pressure drop so that during recirculation, a significant amount (perhaps 50% of design flow) of tower water is drawn into the loop.

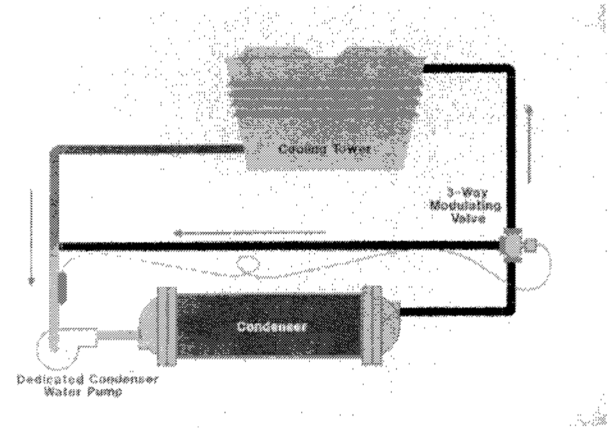


Figure 9

Figure 9 shows the next step in complication. This scheme employs a 3-way control valve to regulate the proportions of recirculated and tower water entering the condenser. The 3-way valve can take the form of two 2-way valves mechanically linked together.

When dedicated condenser water pumps are not possible, control of condenser water temperature is more complex. Depending on the size and type of cooling tower, it may be possible to control sump temperature by bypassing the entire system flow back into the sump, as shown in Figure 10.

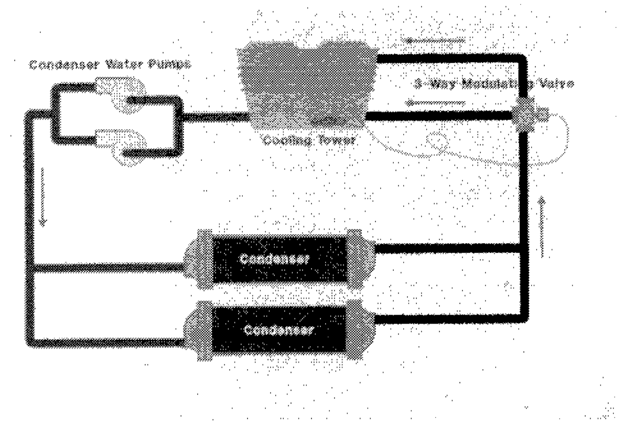


Figure 10

Some towers cannot tolerate loss of flow in cold weather. And, some systems are so large that it takes too long for such a bypass system to gain control over the water temperature.

Before adding complexity of this magnitude, the designer should evaluate the need for control. Large systems often remain active day, night, and on weekends. Heat rejected into such systems is usually sufficient to allow normal fan control to hold temperature. When a cooling tower system is very large, compared to chiller size, the condenser water system appears "infinite". The same kind of head pressure control system used for infinite sinks can be applied.

Compressor Motor Starter

The starter interlocking explanation, contained in section "System Operation", page 8, applies to star-delta, reduced voltage starters of the closed transition type. Other kinds of starters can be used, but all must be closed transition. (An open transition will be interpreted as a momentary power interruption by the micro circuitry.)

Starter types, other than star-delta, require specific internal parts and interlocking to communicate properly with the micro. In general, the following starter types can be used:

1. Star-delta, closed transition	200- 575 volts
2. Primary reactor, closed transition	2300-5000 volts
3. Primary resistor, closed transition	200- 575 volts
4. Full voltage (X-line)	200-5000 volts

Anyone contemplating the use of a starter other than star-delta, closed transition, should seek specific information about the special requirements and approval for its use.

Caution:
NEVER use shunt-trip or electrically operated circuit breakers or switch gear as replacements for CenTraVac motor starters. These devices are not inherently "fail-safe", and thus they place the compressor motor in significant and unnecessary peril.

Application

The CVHE microprocessor-based control system has been designed to serve a broad range of chilled water applications. Limitations, as applied to chilled water service are:

1. Chilled water temperature setpoint (min deg. F) 37 (extended range 20)
2. Chilled water temperature setpoint (max deg. F) 60 (extended range 70)
3. Reset — Chilled water reset cannot exceed the active setpoint range limits given in items 1 and 2 above.
   Note: Negative chilled water reset is not allowed.
4. Chilled water flow rate (min. gpm/ton) 0.8
5. Chilled water flow rate (max gpm/ton) 8.0
6. Loop water volume (min. gal./ton) 5.0
7. Loop water volume (max. gal./ton) infinite
8. Controller operating ambient (min. deg. F) 32.0
9. Controller operating ambient (max. deg. F) 158.0

When the chilled solution is an anti-freeze (brine) mixture, the minimum chilled water temperature setpoint is lowered to +20 deg. F.

Single Chiller Systems

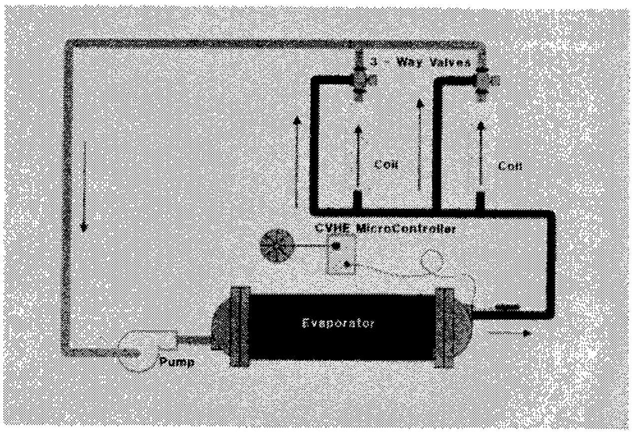


Figure 11

Basic Control. . .The basic single chiller loop is shown in Figure 11. Matching CVHE capacity with load demand is accomplished by controlling the leaving chilled water temperature at a pre-set value. When the temperature rises above this value, CVHE inlet vanes are opened past their present position. Conversely, when the observed chilled water temperature falls below the preset value, the inlet vanes are moved toward the closed position.

The only other operating signal that can influence the inlet vane position is motor current. A "load-limiting" function prevents the compressor from loading the motor beyond a preset value. This value is generally set at the maximum RLA rating of the motor. However, action of the "demand limiter" can reduce the current to any value, to a minimum of 40% of the load limit setting.

Two safety signals can limit inlet vane position, as well. They are, 1) the low refrigerant temperature limit and 2) the high condenser pressure limit. As either of these limits is approached, inlet vanes are moved toward the closed position.

Control Accuracy. . . The controller algorithms contain routines that provide an inherent accuracy of plus or minus 0.5 F. However, a combination of chilled water loop size and stability may prevent this accuracy from being achieved. In other words, loads can change so rapidly that the controller cannot sense temperature changes quickly enough, or the inlet vanes cannot move to a new position quickly enough to maintain this accuracy. Realistically, we can expect to hold the leaving chilled water temperature within 1 deg. F, if the system delta-T is 15 deg. F or less, and within 2 deg. F if the delta-T is above 15 deg. F.

System size and response characteristics vary widely. Thus, the CVHE control system is provided with a control input named "control response". This control adjusts the "response gain" to accomodate varying system characteristics. This control should be adjusted only by a qualified service engineer, since improper adjustment can lead to "hunting" or other unwelcome peculiarities.

The start/stop differential can be set manually to lengthen or shorten cycle times between starts. The "differential to start" control measures the difference between the actual chilled water temperature and the chilled water setpoint. A minimum difference turns the chiller off. This event occurs when minimum chiller capacity exceeds load demand long enough for the entire loop to fall to this value.

Likewise, when the chiller is off, a rise in the system water temperature to the other end of the differential setting will cause the chiller to restart. Cycle times are lengthened by using a large differential and vice-versa. Small chilled water loops generally require a large differential setting to limit cycling.

Variable Flow. . . Controller algorithms permit application of the CVHE CenTraVac to variable chilled water flow schemes, so long as they meet each of the following criteria:

1. Minimum and maximum flows within the cataloged limits for the specific evaporator size.

2. Changes in flow rate do not exceed a rate of 2% of design flow/minute. For example, a maximum change rate of 20 gpm/minute for a nominal 1000 gpm system.

Process Chilled Water Systems. . . In general, load changes associated with air conditioning applications occur slowly and predictably. The application of CenTraVacs to process chilled water loads opens up the possibility of:

1. Loads that come and go quickly and without warning.

2. Loads that require extremely precise temperature control.

3. Loads that return "used" chilled water to the chiller at temperatures well above the maximum safe return water temperature.

4. Loads that require a supply water temperature well above the maximum permitted.

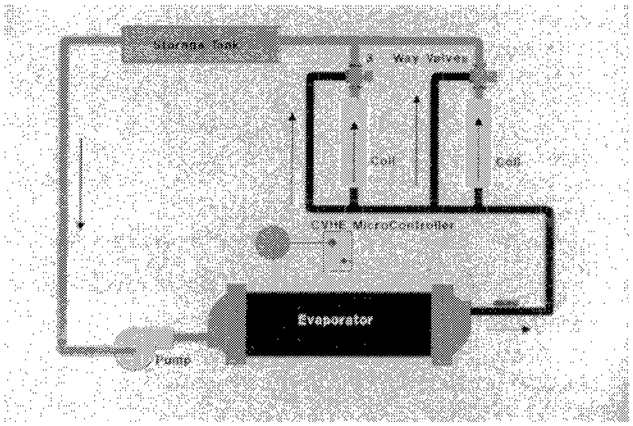


Figure 12

Figure 12. Suddenly appearing or disappearing loads, in themselves, may not be a problem. However, when temperature stability limitations accompany them, a "thermal flywheel' of some sort may be required. Many designers feel a storage tank is the answer. Possibly so. But, in many cases a storage tank does nothing but delay the problem of sudden load changes. In effect, the tank becomes a longer chilled water supply or return pipe. The magnitude of the temperature upset is not changed. Instead, it's appearance at the chiller is simply delayed.

Application

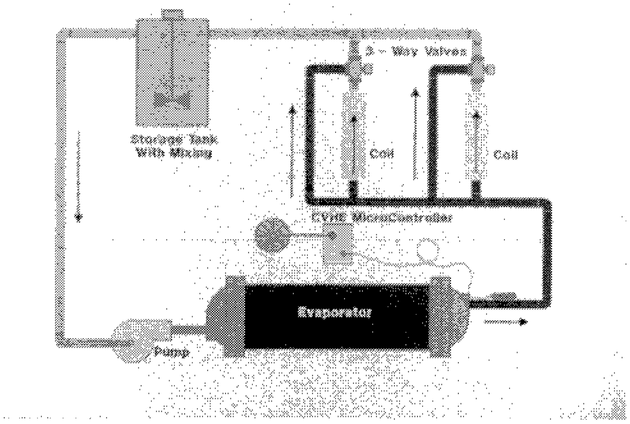


Figure 13

To achieve a flywheel effect, the tank must be a mixing chamber. In this way, water returning to the chiller is allowed to assume a "floating average" temperature before exiting the tank, Figure 13.

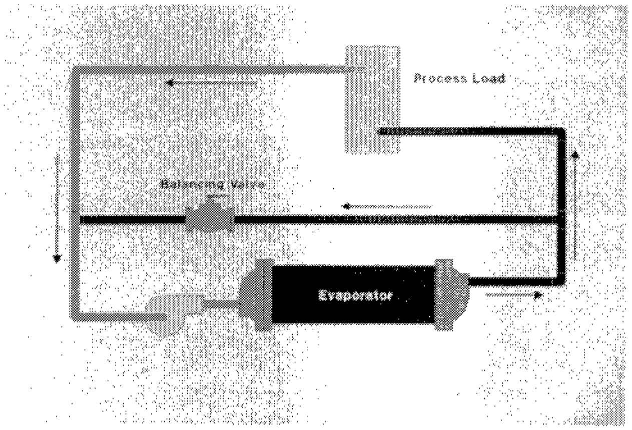


Figure 14

Figure 14. To prevent excessively warm water from returning to the chiller, a separate bypass loop must be established. A single circulating pump can be used if the chiller flow rate always exceeds the process demand. Surplus flow is sent through the bypass line into the return and mixed with return process water. If load changes are sudden, the return "tee" actually becomes a mixing tank, as shown in Figure 15.

Figure 16. When the process loads operate at supply and return temperatures above those allowed in the chiller, two circulating pumps are required. Two loops (process and chiller) are interconnected by bypass piping. Flow in the process bypass pipe is controlled by a temperature controller set at the desired process supply value.

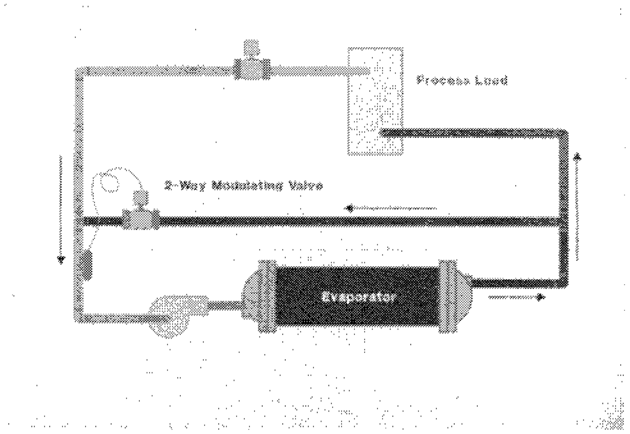


Figure 15

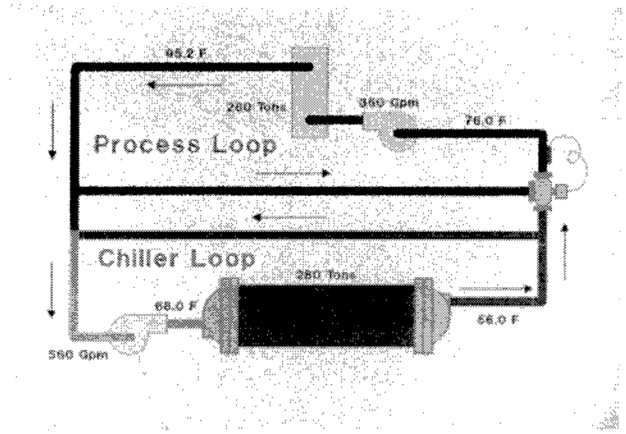


Figure 16

Flow in the chiller bypass line, then, automatically assumes the balanced rate. Temperature mixing equations are used to calculate the various design flow rates, and the controller does the rest.

Example: Assume a maximum process load demand of 280 tons, cooling 350 gpm from 95.2F to 76.0F. Also, assume a chiller is selected to provide 280 tons, cooling 560 gpm from 68.0 to 56.0F.

If "X" is the flow in the interconnecting link piping,the mixing equation is: $56.0X + 95.2(350-X) = 76.0(350)$, or $56.0X-95.2X = 26600-33320$, or $X = 171.43$

Therefore, the design load flow rate in the process bypass line is 350 - 171.43, or 178.57 gpm. Likewise, the flow in the chiller bypass line is 560 - 171.43, or 388.57 gpm.

Multiple Chiller Systems

Certain kinds of multiple chiller systems involve "integrated" control strategies. That is, a higher level control authority instructs unit-level controllers in a predetermined way to act as a complete system.

Other multiple chiller systems are put together in such a way as to allow individual chillers to act independently. No higher level authority is required to coordinate the control of individual chillers. An example of one such system is shown in Figure 17.

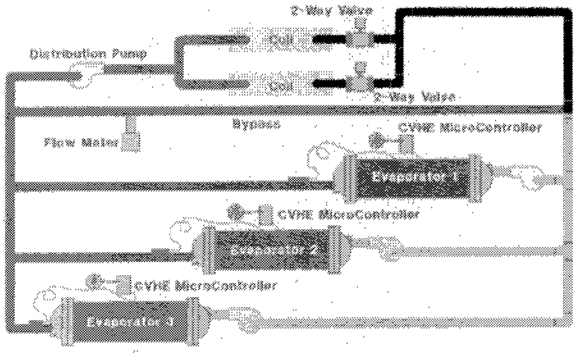


Figure 17

The primary/secondary pumping arrangement is used commonly to handle multiple chiller systems. This particular hydraulic combination decouples the distribution circulation from the production part of the system. In operation, a simple flow measuring controller decides how many chiller/pump "production units" are needed. Once this decision is made, the CVHE unit-level controller accepts all responsibility for temperature control.

Chilled water temperature control is separate from system control. Thus, any number of independent chilled water temperature controllers can operate on the same system. While it makes sense to have all such controllers set at the same setpoint, there is nothing to prevent different setpoints. However, different setpoints cause varying system supply water temperatures as different chillers are brought on line.

The common return water temperature establishes individual chiller demands for capacity. Since the return temperature is the same for all operating chillers, they share total system load in proportion to their pump's flow rate. "Preferential" loading is possible only by rearranging the hydraulics, as shown in Figure 18. When the common bypass (decoupler line) is placed "outside" a production chiller/pump "production unit", that unit can be preferentially loaded. This occurs because its return water temperature is not diluted (decreased) by water flowing through the bypass from the supply main.

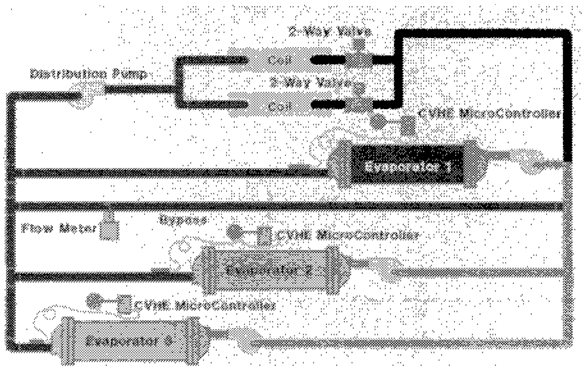


Figure 18

Series flow chillers. . . When evaporators are piped in series, Figure 19, it is possible to control the chillers separately and independently. The chilled water control set points are based on:

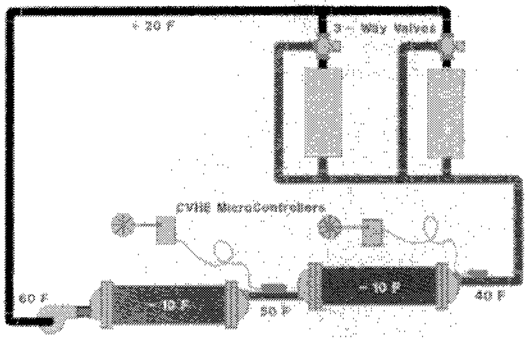


Figure 19

1. Setting both chillers to the system design water temperature. This method loads the upstream chiller first in sequence.

2. Setting only the downstream chiller at the system design water temperature. By setting the upstream chiller at the design intermediate temperature, it will be sequencially loaded last.

Application

Heat Recovery

CVHE chillers applied as heat recovery machines present unique control challenges. The basic water chiller control system does not recognize heat recovery control as being different from conventional chilled water control. To apply CVHE CenTraVacs to heat recovery service, a basic control strategy must be selected. There are several to choose from:

1. Auxiliary Heat Recovery. . . Figure 20. Control of CVHE inlet vanes remains with the leaving chilled water temperature controller. One method to establish a suitable heat recovery temperature level is to use the same kind of condenser head pressure control described in the "Condenser Water Control" section, page 16. This heat recovery system is characterized by its inability to absorb all of the heat rejected by the refrigeration system. Therefore, the main heat sink must be capable of accepting all rejected heat at any time.

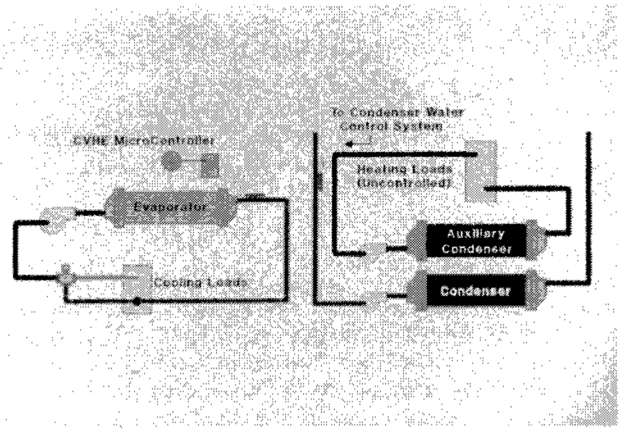


Figure 20

Head pressure control permits this while maintaining a condensing pressure (and temperature) high enough for auxiliary heat recovery.

2. Controlled Heat Recovery. . . Figure 21. When the heat recovery circuit is capable of absorbing all rejected heat during this mode of operation, the temperature of the returning hot water is used to control the amount of heat (usually by water flow) directed to the cooling tower water circuit. This also leaves inlet vane control completely under the control of the leaving chilled water controller. The basic CVHE control system is unaffected.

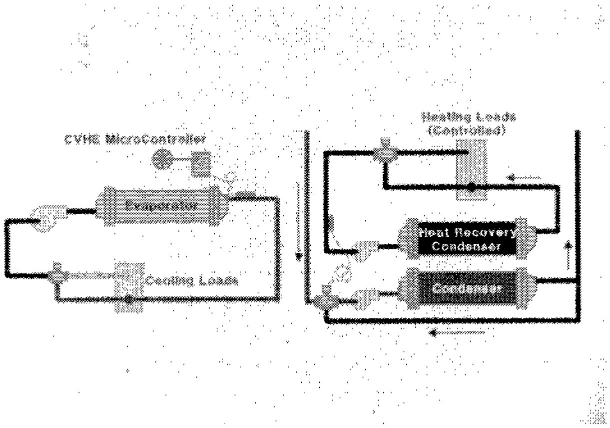


Figure 21

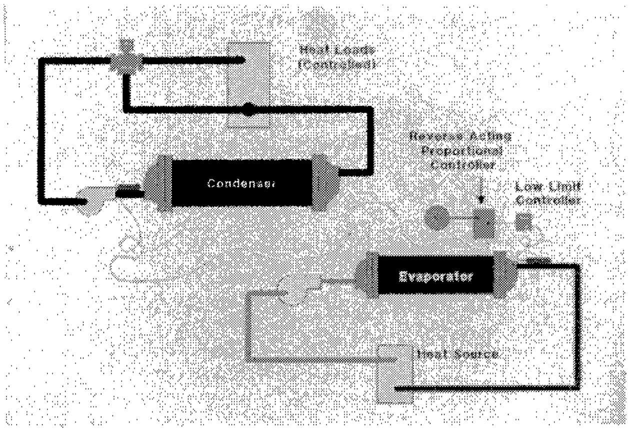


Figure 22

3. Heating As Primary Mission. . . Figure 22. In this case, the importance of heating transcends that of chilling water. The CenTraVac becomes primarily a heating device. This kind of system is used when the heat source, rather than the sink, is infinite. There is no possibility of running low on either chilled water flow or temperature. Control of the inlet vanes is taken away from the leaving chilled water controller and given to a heating water temperature controller.

For information pertaining to converting the CVHE controls for heating priority, refer to Trane Engineering Bulletin CTV-EB-91.

Interfacing With Other Control Systems

While the CVHE control system is microcomputer-based, its language and protocol are not common to control systems marketed by other control manufacturers. Therefore, it is not possible to simply tie a pair of wires into the micro with the hope of passing information and data back and forth.

Instead, a "translator" is needed. This function is filled by a system control panel, model SCP 699. In general, all remote interfaces, except the following listed ones, require an optional SCI (serial communications interface) and a Trane SCP 699 system control panel.

On-Off. . . Remote control of the on-off (start/stop) function can be executed through the optional "translator" panel SCP 699. If this is the only remote function that is desired, a less costly, but less friendly interface is possible. One way to accomplish it is to break into the chilled water interlock circuit. The circuit is identified by terminal pairs 1 TB5-15/17, Figure 5 line 24. This is less friendly because an interruption of the circuit causes a non- latching diagnostic. While the message indicates flow interruption, the operator can never be sure whether a flow failure has actually occurred or the unit is being turned off by the remote device.

Alarms. . . Remote alarm systems can be connected to the (optional) relay package (1U1, Figure 5). A customer-supplied, self powered alarm device can be activated by this pair of dry contacts, either normally closed or normally open. Any of the several CenTraVac alarm sequences will cause a signal to change contact position. Since there is a single alarm point, this circuit will not give an indication of the specific alarm condition.

A second alarm relay contact pair (head relief request relay) is included in the optional relay package. This relay is activated whenever the standard surge protection feature detects compressor surge. A request for condenser head relief can be used to remotely 1) reset existing condenser water temperature controls, 2) activate additional supplies of condenser water, or 3) signal any other remote and existing apparatus that will lower the condenser refrigerant pressure. This contact pair cannot be used as a controller output because it is not driven by control algorithms.

Hot Gas Bypass

The purpose of compressor discharge hot gas bypass is to false load the compressor with sufficient gas volume so as to maintain stability. Basic CVHE compressor stability is unusually high due to the three-stage design and the use of pre-rotation inlet vanes ahead of each stage. The inlet vanes ahead of the first and third stages are positioned by the temperature control system.

This permits the CenTraVac to be applied to systems that require aggressive turn-down ratios. Rule of thumb, CenTraVacs will operate with high stability at loads as small as 10% of the chiller's maximum capacity. In many cases, stable operation can be expected at even lower loads (sometimes on only system pipe gains).

On rare occasions hot gas bypass is necessary to false load a compressor to achieve a high pressure ratio at low "real" loads. Or, the start/stop cycling that occurs at loads below minimum loading may be unacceptable. In either event, control over hot gas bypass is executed by four devices contained in an optional hot gas bypass kit:

1. Hot gas bypass relay (1K15). Allows the inlet vanes and the hot gas bypass valve to close on chiller shutdown.

2. Inlet vane end switch (4S4). Permits adjustment of the activation point for the hot gas bypass, depending on inlet vane position.

3. Hot gas bypass valve switch (4B5). Directs "vanes close" or "vanes open" signals to the inlet vanes or to the hot gas bypass valve, depending on the relative position of each.

4. Discharge temperature switch (4S5). Shuts down the chiller if the compressor discharge temperature exceeds 210 deg. F., which may be caused by excessive no-load operation.

The hot gas bypass valve option should not be applied to a chiller indiscriminantly. It is not a cure-all for poor system design.

Free Cooling

The CenTraVac free-cooling option consists of five additional items:

1. Refrigerant gas line to bypass the compressor, including electrically actuated two-position valve.

2. Refrigerant liquid return line from condenser to evaporator, including electrically actuated two-position valve.

3. Liquid refrigerant storage vessel (actually, an extension to the existing economizer vessel).

4. Additional refrigerant charge to provide added wetted evaporator tube surface.

5. Free-cooling selector switch.

Application

When a CenTraVac operates on the free cooling cycle, temperature control is lost. The chiller simply becomes a pair of heat exchangers that permit heat from the chilled water loop to be rejected into the cooling tower circuit. The balance between the chilled water load and available condenser water temperature will produce an equilibrium condition at some leaving chilled water temperature.

This will likely not be the design system chilled water temperature. So long as it meets the needs of the system, however, free cooling is appropriate. When the derived chilled water supply temperature no longer satisfies system needs, it is time to switch the system over to "powered" cooling. This change-over is executed manually.

Since the condenser water temperature, at the time of change over, is likely to be low, some form of condenser water control is desirable (if not mandatory). The various options are listed in the "Condenser Water Control" section, page 16.

Low Temperature (Brine Chilling)

Model CVHE CenTraVacs may be applied as low temperature brine chillers.

Chiller modifications are limited to the control systems and various safety cutout settings. In other respects, the CenTraVac is essentially the same as a conventional water chiller.

Systems of this type often require two chilled water temperature control setpoints. One is used for ice-building and the other for conventional operation. To perform this change, a remote setpoint adjustment should be used. As indicated in the "Interfacing with Other Control Systems" section, page 23, the serial communications interface and the SCP 699 interface panel must be used to perform remote setpoint changes.

Appendix

The following describes the "Last Diagnostic" codes (Prefix b) displayed when an abnormal CenTraVac shutdown occurs.

Unit Diagnostics Condition

Code	*Description*
A3	Evap. Refrig. Temp. Range
A4	Motor Temp. Sensor #1
A5	Max. Accel. Time Range
A7	Motor Temp. Sensor #2
A8	Motor Temp. Sensor #3
A9	Oil Temp. Sensor
Ab	Leaving Water Temp. Sensor
Ac	Cond. Refrig. Pressure Sensor (Opt.)
Ad	Evap. Refrig. Temp. Sensor
AE	Ambient Temp. Sensor (Opt.)
AF	Bearing Temp. Sensor #1 (Opt.)
b0	Bearing Temp. Sensor #2 (Opt.)
d9	Extended Power Loss
dA	Surge
dc	Cond. Water Flow Overdue
dE	Cond. Pressure Start Inhibit
E2	Momentary Power Loss
E3	Phase Imbalance
E4	Phase Loss

Code	*Description*
E5	Phase Reversal
E7	High Motor Temp.
E8	Differential Oil Pressure Switch
E9	Stop Relay
EA	High Bearing Temp.(Sensor #1)
Eb	High Bearing Temp. (Sensor #2)
Ec	Running Overload
Ed	Chilled Water Flow
EE	Exceeded Max. Accel. Time
F0	Transition
F1	Running Ext. Interlock (Opt.)
F2	Low Oil Pressure
F4	High Oil Temp.
F5	High Cond. Refrig. Pressure
F7	Cond. Water Flow
F8	Improper Unit I.D.
F9	Free-Cool. Valves
FA	Actuator
Fb	Low Evap. Refrig. Temp.
Fd	External Interlock (Opt.)
FF	Unit Control Module

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